

# DEVELOPING A CORAL REEF MONITORING PROGRAM FOR THE NATIONAL PARK OF AMERICAN SAMOA:

## A PRACTICAL, MANAGEMENT-DRIVEN APPROACH FOR SMALL MARINE PROTECTED AREAS

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**SUMMARY:** The National Park of American Samoa has three small marine protected areas in the Samoan Archipelago, central South Pacific Ocean. At present, the Park is in an early stage of development with low visitation by tourists; Park uses are primarily subsistence fishing by local villagers. A 'Vital Signs' workshop was held to develop a coral reef monitoring program for the Park, where the intent was to focus on the most significant indicators (i.e., the vital signs) of long-term ecological trends or priority concerns of the Park. The workshop first identified who the monitoring program was for (the on-site manager) and then examined what information the manager needed and why. That, in turn, required knowledge of natural environmental changes and threats to the Park's reefs, which are presently local fishing pressure and natural forces (e.g., hurricanes, increased mortalities due to global warming). Monitoring questions related to these natural changes and threats were formulated, followed by a listing of indicators that would provide the desired information by tracking changes in reef condition over time. The vital signs selected were human uses of the park and selected parameters for corals, other invertebrates, fish, algae, and water quality. Vital signs were identified that should be measured regularly (at least yearly), or less frequently to document baseline conditions for possible future comparisons. This vital signs approach provided a convenient way to identify, organize and prioritize the variables that should be included in a monitoring plan. It also identified some needs that exceed current Park capabilities. The next steps in this process will be to determine appropriate sampling designs and methods for the monitoring program.

## Table of Contents

|   |    |
|---|----|
| Introduction.....                                   | 3  |
| Workshop focus.....                                 | 3  |
| What is a 'vital signs' workshop?.....              | 3  |
| Who is this monitoring program for?.....            | 4  |
| Program goals.....                                  | 4  |
| Definitions.....                                    | 4  |
| A practical approach.....                           | 5  |
| Comparisons with other studies in Territory.....    | 5  |
| Territorial setting.....                            | 5  |
| Environmental trends in the Territory.....          | 6  |
| Threats to coral reefs in the Territory.....        | 7  |
| Marine protected areas in the Park.....             | 9  |
| General description.....                            | 9  |
| Threats to coral reefs in the Park.....             | 10 |
| Vital signs to monitor coral reefs in the Park..... | 12 |
| What's next?.....                                   | 15 |
| Literature cited.....                               | 15 |
| Appendix 1. Workshop participants.....              | 16 |

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## INTRODUCTION

There is worldwide interest in monitoring coral reefs for two general reasons. First, coral reefs are among the most diverse and productive communities on Earth and they provide an important source of food, coastal protection from severe weather, potential natural products, and revenue from tourism. Second, alarms have been sounded that coral reefs worldwide are showing signs of stress and mortality from both natural and human causes. It has been estimated that two thirds of reefs worldwide have been degraded, 10% of them "beyond recognition" (Brown et al. 1999).

Several international workshops have convened to address these issues and manuals have been prepared that describe methods for monitoring coral reefs (e.g., Rogers et al. 1994, English et al. 1997, Samoilys 1997, Maragos & Grober-Dunsmore 1999). The National Park Service also provides its approach to ecosystem monitoring on its website: [www.nature.nps.gov/im/monitor](http://www.nature.nps.gov/im/monitor).

The purpose of the present workshop was to view coral reef monitoring from a small park perspective, where local resources are far fewer than occur in more developed states or countries with numerous management agencies and academic institutions. The challenge was to determine what information is needed for practical management of coral reefs and what tasks can realistically be accomplished by managers of small (and often remote) marine protected areas.



Figure 1. Location map.

In the past two years, American Samoa (Fig. 1) has conducted two inter-agency coral reef workshops that identified the major natural and anthropogenic stresses to coral reefs in the Territory and began charting a course for monitoring and research (Craig et al. 1999). In view of the Territory's small size, most of the issues raised at those earlier workshops are also directly relevant to the National Park of American Samoa (NPSA). Consequently, we are able to build upon these previous efforts to focus on specific monitoring needs within the Park. To develop this plan, NPSA invited a group of local and off-island specialists to participate in a 'Vital Signs' workshop held in June 2001. Participants are listed in Appendix 1.

## WORKSHOP FOCUS

**What Is A 'Vital Signs' Workshop?** 'Vital Signs' is the name used by the National Park Service to describe its monitoring programs. It refers to key elements that indicate the health of an ecosystem, and the intent of the workshop was to focus on the most significant indicators of long-term ecological trends or priority concerns of the Park. In this workshop, we followed the Lake Mead template (NPS 1999) for conducting a workshop that links many of the vital signs to anthropogenic stresses to the ecosystem, because this could potentially lead to corrective management actions by the Park. Other vital signs tracked natural changes in the reef environment to alert managers to changes in reef condition that might require targeted research. Monitoring questions related to those stresses and natural changes were formulated, followed by a

listing of vital signs that would provide the desired information. We found this approach to be a convenient way to identify, organize and prioritize the variables that should be included in a monitoring program.

The vital signs selected depend on what questions are being asked. That, in turn, requires that we first identify who and what the monitoring program is for, and then clearly state what information is needed and why. Some of the information selected would probably be common to almost any coral reef monitoring program, but by also examining specific natural and anthropogenic threats to the local environment, we are able to identify additional information that will likely be needed.

NPSA adds an additional consideration to the vital signs approach: it has to be practical and achievable for a small park or a small marine protected area. In other words, we should plan comprehensively and for the future, but start with the highest priorities and with what available resources will allow.

**Who Is This Monitoring Program For?** Different user groups may have different needs, so it is important to identify at the start who this program is intended for. In this plan, the primary target user of this monitoring plan is the on-site Park manager, thus the plan focuses on management-driven questions from the manager. It is recognized, however, that the manager will need input from researchers, local stakeholders and others to help identify important issues and develop a monitoring plan.

**Program Goals.** NPSA's goals for a long-term monitoring program are to:

- Assess the health (changes in condition over time) of the coral reef environment,
- Detect short- and long-term environmental change,
- Provide information on whether these changes are within the normal range of variation,
- Provide insight into the ecological, sociological and economic causes and consequences of these changes,
- Determine if the observed changes require a change in management practices.

At the same time, however, we must recognize that there are few data describing what is a "normal range" of variation for coral reefs in American Samoa -- these ranges will only begin to emerge after 10 or more years of monitoring. Even then, we must also recognize that the relatively rapid affects of global warming or climate change may well cause changes that exceed the previously observed "normal range" of variation (as measured on the relatively short timeframe of the human lifespan).

### **Definitions.**

**(a) Monitoring:** the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective. The key points here are that (1) the same methods are used to take measurements over time, (2) monitoring is done for a specific purpose, usually to determine progress towards a management objective, and (3) some action will be taken based on the results, even if the action is to maintain the current management. This report focuses on long-term monitoring.

**(b) Vital Signs:** key biological, physical or chemical elements or processes that indicate the health of the ecosystem. Vital signs can be any feature of the environment that can be measured or estimated and that provides insight into the state of the ecosystem.

**(c) Reef health** We use the term 'reef health', because it is convenient for our purposes and it is consistent with the 'vital sign' analogy used in this report. To the manager, examples of 'poor health' include habitat degradation caused by natural or anthropogenic factors such as hurricanes that lead to, for example, a low percentage of live coral cover and reduced habitat complexity, or extensive coral mortalities due to warm-water bleaching, increasing levels of disease, or an increase in fleshy algae resulting from nutrient enrichment, all measurable over time.

**(d) Artisanal fishery:** small-scale commercial catches that are sold in local markets.

**A Practical Approach.** As a guideline, a monitoring program for NPSA should include the following elements:

- Management-driven approach. Managers need to determine and clearly state what information they need and why, and performance indicators need to be identified and monitored through time to see if the information collected is adequate and appropriate.
- Comparable to other programs. To the degree possible, methodology should be consistent with methods used to monitor coral reefs in other areas (note that methods are not discussed in this report).
- Resilient to fluctuating expertise. On-island capabilities and expertise fluctuate on a regular basis as professional staff rotate through American Samoa.
- Achievable with local staff. While recognizing that off-island expertise will be needed to address some issues or conduct detailed studies at multi-year intervals, other aspects of a monitoring program can and should be accomplished with local resources.
- Interactive with the community. Maintain local community input and dialog. Findings should be reported in a manner understandable to both managers and the public.
- Cost-effective.

**Comparisons With Other Studies In The Territory.** We did not examine the merits or locations of on-going or past studies in the Territory until we first determined our own information needs. Following that, it is appropriate to examine how other studies may be compatible with the needs identified in this workshop.

## **TERRITORIAL SETTING**

American Samoa consists of five volcanic islands and two atolls in the central South Pacific Ocean (14° S, 168-173° W). The islands are small, ranging in size from the populated high island of Tutuila (142 km<sup>2</sup>) to the uninhabited and remote Rose Atoll (4 km<sup>2</sup>). Due to the islands' small size and steepness, shallow water habitats around the islands are limited and consist primarily of fringing coral reefs (85% of total coral reef area) with a few offshore banks (12%) and two atolls (3%). The fringing reefs have narrow reef flats (50-500 m) and depths of 1000 m are reached within

2-8 km from shore. Severe storms occur every few years and hurricanes hit periodically, the last four occurring in 1966, 1986, 1990 and 1991.

Coral reefs in the Territory support a diverse assemblage of 890 fishes, 200+ corals, and 80 algal species. The fish and shellfish are harvested in two local fisheries: subsistence catches, and artisanal catches that are sold locally (Craig et al. 1993). Other potential uses of the reefs are low at present (e.g., tourism or the extraction of reef products for the aquarium trade).

**Environmental Trends In The Territory.** Several trends in local environmental conditions (Craig 2001) set the stage for the issues discussed in this workshop:

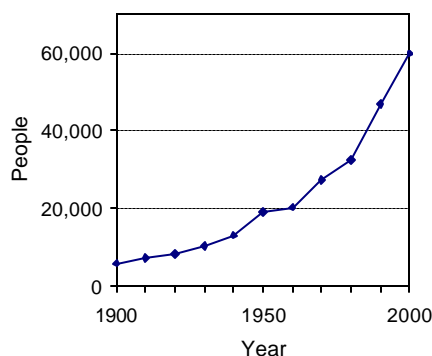
Corals are recovering well from previous natural disturbances. Local reefs were severely damaged over the past two decades by a crown-of-thorns starfish invasion (1978), three hurricanes (1986, 1990, 1991), mass coral bleaching due to warm temperatures (1994), as well as chronic human impacts in populated areas. But by 1995, the reefs were beginning to recover, as evidenced by an abundance of young corals, and the recovery has continued through 2001 (Mundy 1996, Green et al. 1999, Birkeland, in prep.)

Reefs are overfished. Harvested species such as giant clams and parrotfish are overfished, and there is heavy fishing pressure on surgeonfish (Craig et al. 1997, Page 1998, Green and Craig 1999). We also see fewer or smaller groupers, snappers, parrotfish and sea turtles (Tuilagi and Green 1995). Since 1995, the nighttime artisanal spear fishermen began using scuba gear, greatly increasing their catches. This led to a territorial ban on scuba-assisted fishing in April 2001.

Sea turtles are declining. Often overlooked as a part of the coral reef ecosystem, hawksbill sea turtles feed on sponges and other reef organisms. Hawksbill populations are in serious decline for two major reasons: harvest and loss of nesting habitat (Tuato'o et al. 1993). The hawksbill is listed as 'Endangered' and it is rapidly approaching extinction in the Pacific (Eckert et al. 1998). Green sea turtle populations in the South Pacific have declined as well and should probably be classified as 'Endangered' (Eckert et al. 1998). Conservation efforts are complicated by the turtles' complex migration patterns (some migrate from American Samoa to Fiji and French Polynesia), which will necessitate international cooperation to conserve 'shared' turtle stocks.

Human population growth strains environment. One of the most serious environmental problem facing the Territory is its rapid population growth rate (Fig. 2). The population of about 57,300 in 2000 has increased during the past decade at an annual rate of 2.1%, which equates to an increase of about 1,200 people (mostly infants) per year (Craig et al. 2000). Environmental issues include: extensive coastal alterations, pollution, soil erosion and coastal sedimentation, loss of wetlands, overfishing.

Fig. 2. Population growth in A. Samoa.



Environmental enforcement is low. Environmental violations are more frequently detected and prosecuted than in the past, but enforcement of environmental regulations is not widespread and many problems persist. Illegal fishing is a common problem in most of the small marine protected areas that currently exist in the Territory: Rose Atoll National Marine Refuge, Fagatele Bay National Marine Sanctuary, National Park of American Samoa, Vaoto Territorial Marine Park.

Climate is changing. Increased occurrences of warmer-than-usual sea surface temperatures (SST) have been occurring in the South Pacific Ocean. A broad band of high SSTs has developed in recent summers, perhaps in conjunction with La Nina conditions, just south of American Samoa (Fig. 3). It has caused massive coral bleaching and mortalities in nearby Fiji and western Samoa, and it would seem highly probable that corals in American Samoa may be hit as well.

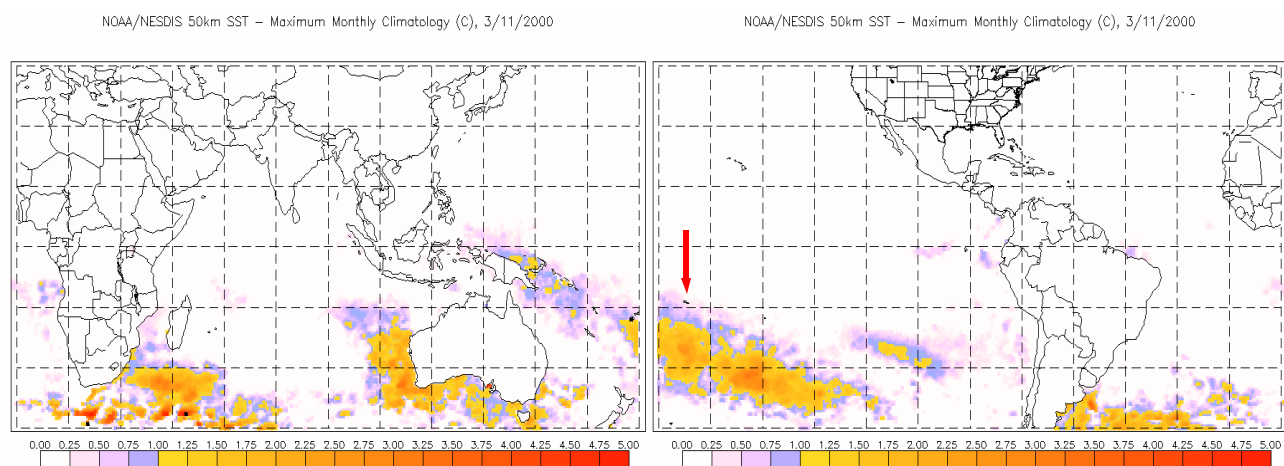


Figure 3. Broad band of high SSTs (gray patches in ocean areas) that develop during summer months near American Samoa (arrow). NOAA/NESDIS satellite data (3/11/2000).

**Threats To Coral Reefs In The Territory.** A previous workshop (Craig et al. 1999) identified primary threats to coral reefs in the Territory, and this list was updated at a second workshop in January 2001 (Table 1).

During these workshops, it was noted that there are three general types of nearshore habitats in the main islands of American Samoa: (1) the industrialized Pago Pago Harbor, (2) the populated south shore of Tutuila Island where most human population expansion is occurring, and (3) everywhere else, including NPSA, where relatively few people live and development activities, if any, center around village sites. Serious pollution problems are generally confined to the harbor, although water quality problems do arise in other populated areas. It was concluded (1) that overfishing was a serious and urgent problem on coral reefs in American Samoa, (2) poor water quality in Pago Pago Harbor still did not promote coral reef recovery, safe swimming or fish that are safe to eat, (3) the Territory's high growth rate continues to strain the environment, and (4) there was a need to re-emphasize to government officials that poor land-use activities were significant contributors to coral reef degradation.

**TABLE 1.** Threats to coral reefs in the Territory, ranked as being a high (H), medium (M) or low (L) concern, based on previous workshop efforts in American Samoa (Craig et al. 1999).

| (i) <u>Human-related impacts</u>   | Priority |
|--|----------|
| Overfishing of reef resources  | H        |
| Coastal development & habitat destruction  | H        |
| Watershed alteration and coastal sedimentation   | H        |
| Pago harbor toxicity   | H        |
| Dumping/improper waste disposal  | M        |
| Nutrient loading/eutrophication in Pago Harbor   | M        |
| Nutrient loading/eutrophication other than Pago Harbor                                   | L        |
| Oil and hazardous waste spills other than Pago Harbor                                    | L        |
| Ship groundings  | L        |
| Anchor damage  | L        |
| Destructive fishing methods  | L        |
| Marine debris from marine sources  | L        |
| Alien species (e.g., from ballast water)   | L        |
| Collections for aquarium market  | L        |
| Bio-prospecting/natural products   | L        |
| <br>(ii) <u>Threats that are a natural part of the ecosystem and/or we cannot affect</u> |          |
| Hurricanes   | H        |
| Global warming in American Samoa   | H        |
| Harvest of Samoan sea turtles in foreign waters  | H        |
| Increased UV radiation due to ozone depletion  | M        |
| Crown-of-thorns starfish predation   | M        |
| Coral diseases   | L        |
| <br>(iii) <u>Related management issues</u>   |          |
| Human population growth on Tutuila Island  | H        |
| Need to develop a Marine Protected Area network  | H        |
| Need for a territorial monitoring program  | H        |
| Need for reef maps and GIS database  | H        |
| Need for a socio-economic valuation of coral reefs                                       | H        |
| Need increased education efforts for reef conservation                                   | H        |
| Lack of biological information needed for management                                     | H        |
| Lack of agency capacity  | H        |
| Lack of stakeholder participation  | H        |
| Lack of public support for regulations   | H        |
| Lack of enforcement  | H        |
| Lack of political will to support management   | H        |
| Breakdown of traditional values  | H        |
| Need for reef restoration  | M        |
| New industries for coral resources   | M        |



## MARINE PROTECTED AREAS IN THE PARK

**General Description.** NPSA is a relatively new, developing Park. Although established by Congress in 1988, it was not until 1993 that the land lease agreements were signed with the nine villages that own communal land within the Park. Since then, NPSA has grown to about 12 FTE, of which 3 marine resources staff (2 biologists, 1 technician) will be in place by 2002.

The Park consists of 8000 acres of paleotropical rainforest and 2,550 acres of Indo-Pacific coral reefs, located on three islands in the Samoan Archipelago: Tutuila, Ofu and Ta'u (Fig. 4). In all Park units, the marine boundary extends 0.25 miles offshore which occurs at about the 100-ft depth contour. Some unit specifics are:

- Tutuila Unit: 1,200 marine acres on the northern (leeward) side of island, nearly continuous coral reefs, some coral and fish surveys have been conducted (e.g., Green 1996, Green and Hunter 1998).
- Ofu Unit: 350 marine acres, including an unusual backreef lagoon that supports a diverse assemblage of coral and fish species (e.g., Hunter et al. 1993, Craig et al. 2001).
- Ta'u Unit: 1,000 marine acres, remote, corals growing on basalt with limited fringing reef development, water conditions usually rough, largely unsurveyed.

While surveys within the Park are limited, territory-wide species lists demonstrate a moderately high diversity of tropical marine species: 890 nearshore fishes and 200+ corals. The number of marine endemic species is not known at present but is thought to be low due to the wide distributions of most marine organisms occurring in the region. Federally listed threatened or endangered species include humpback whales and green and hawksbill sea turtles.

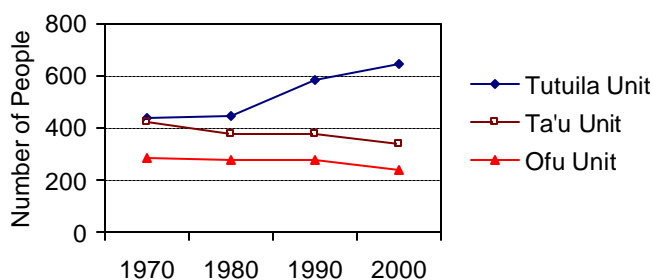
At present, human use of the Park primarily consists of subsistence fishing and agriculture, both allowable activities by resident Samoans in the villages adjacent to the Park. Subsistence harvests of fish and invertebrates in the Park have not yet been documented.

Population growth rates in these villages are increasing on the main island of Tutuila (where 96% of the Territory's population resides), but negligible or declining on Ofu and Ta'u islands as villagers move to Tutuila for employment, etc. (Fig. 4).

Tourism is low at present and it appears that it will take some time before American Samoa gets into the mainstream of South Pacific tourism

like Tahiti or Fiji. Further, within the Park units there is limited access to beaches in the Tutuila Unit, the Ta'u Unit currently lacks services or camping areas, and visitation to Ofu (which has both access and services) averages only about 2 people per day at present. Estimated tourist visitation to the Park was low in 2001 but growing slowly (Table 2).

Fig. 4. Average village size



**TABLE 2.** Estimated tourist visitation and subsistence use of NPSA in 2001.

| Park Area         | Annual<br>tourist<br>visitor-days <sup>1</sup> | Tourists<br>using Park<br>marine areas <sup>2</sup> | Marine<br>subsistence<br>users <sup>3</sup> |
|-------------------|--|---|---|
| Tutuila Park unit | 1000   | 200   | 3 villages                                  |
| Ofu Park unit     | 1000   | 700   | 2 villages                                  |
| Ta'u Park unit    | 20   | 10  | 1 village                                   |

<sup>1</sup> Visitor days as used here do not include low impact uses such as driving through Park or picnicking.

<sup>2</sup> Swimming, snorkeling, diving, boating, beach activities

<sup>3</sup> Population sizes of the individual villages listed in the table above: Tutuila (600-800), Ofu (250-350), Ta'u (460).

**Threats To Coral Reefs In The Park.** Building upon previous workshops that identified threats to coral reefs in the whole Territory (Table 1), we summarize current and foreseeable threats to coral reefs within the Park in Table 3.

Fishing pressure was identified as the potentially most significant threat to coral reefs in the Park that we might be able to do something about. Following that, important natural disturbances were hurricane damages and potentially increased coral mortalities due to climate change. Other threats common to all Park units were that sea turtle populations have declined throughout the region due to overharvest and habitat loss, and the incidence of coral diseases, while presently low, may become of concern if corals become stressed by increasing water temperatures, etc.

Additional threats specific to a Park unit are:

- **Tutuila Unit.** In addition to subsistence fishing (which is permitted), illegal artisanal (small-scale commercial) fishing also occurs. Page (1998) estimated that 9% of artisanal catches occur within the Park, which occurs at night in remote areas, and NPSA lacks enforcement capabilities at present. Other direct or indirect threats are due to population growth. Of all the Park units, the Tutuila Unit would be the one most impacted by population growth because virtually all population growth in the Territory occurs on this island. However, the Park lies on the north side of the island away from southcoast areas where most growth is occurring.
- **Ofu Unit.** This unit is a small 2-mile long strip of land and coastal waters along the southern shoreline of the island. It contains two distinctly different habitats, a shallow-water backreef lagoon that supports a diverse coral and fish assemblage, and a deeper-water area that extends beyond the fringing reef out to the Park boundary 0.25 miles offshore. In this unit, there are three fishing-related issues: selected resources like giant clams may be overharvested in the lagoon, subsistence-caught fish and shellfish are shipped to family members on Tutuila Island, and there is concern that an increasing number of fish may be collected island-wide to supply the larger markets on Tutuila Island. Other lagoon-specific issues include potential recreational impacts, coral

**TABLE 3.** Current and near-term threats and natural changes to coral reefs in NPSA, ranked as being a high (H), medium (M), or low (L) concern.

| Threats to coral reefs                                | All<br>Units | Tutuila<br>Unit | Ofu<br>Unit | Ta'u<br>Unit | <i>SIGNS*</i> |
|---|--------------|-----------------|-------------|--------------|---------------|
| <b><i>NATURAL &amp; HUMAN-RELATED THREATS</i></b>     |              |                 |             |              |               |
| Fishing pressure                                      | H            |                 |             |              | 1-4           |
| Hurricanes  | H            |                 |             |              | 3-8           |
| Global warming (eg, coral mortalities)                | H            |                 |             |              | 3-8           |
| Harvest of Samoan turtles in foreign waters           | H            |                 |             |              | -             |
| Harvest of turtles in local waters                    | M            |                 |             |              | -             |
| Recreational use                                      | M-L          |                 |             |              | 3-7, 9        |
| Coral diseases  | L            |                 |             |              | 5             |
| <b><i>ADDITIONAL THREATS TO TUTUILA PARK UNIT</i></b> |              |                 |             |              |               |
| Illegal non-subsistence fishing in Park               |              | H               |             |              | 2             |
| Impacts related to rapid human population growth      |              | M-L             |             |              | 3-7           |
| -sedimentation (land use, feral pig damage)           |              |                 |             |              |               |
| -nutrient loading near villages                       |              |                 |             |              |               |
| -improper waste disposal                              |              |                 |             |              |               |
| <b><i>ADDITIONAL THREATS TO OFU PARK UNIT</i></b>     |              |                 |             |              |               |
| Recreational impacts to lagoon                        |              |                 | H-M         |              | 3-7           |
| Crown-of-thorns starfish predation in lagoon          |              |                 | M           |              | 4             |
| Pollution from village dump                           |              |                 | M           |              | -             |
| <b><i>ADDITIONAL THREATS TO TA'U PARK UNIT</i></b>    |              |                 |             |              |               |
| Additional threats not identified at this time        |              |                 |             | -            | -             |

\*For cross-reference purposes, most threats listed above will be monitored by specific vital signs (identified by number) that are described in the next section: 'Vital signs to monitor coral reefs in the Park'.

mortalities due to crown-of-thorns starfish which are present in low numbers around the island, and pollution from a village garbage dump adjacent to the lagoon.

Ta'u Unit. This unit is distant from human habitation, thus most threats to its coral reefs are natural disturbances (e.g., hurricanes). But there is also concern that an increasing number of fish may be collected from Ta'u (island-wide) to supply the larger markets on Tutuila Island. Park enforcement on Ta'u is difficult at present due to the remoteness of the area and the absence of a full-time Park presence there.

**VITAL SIGNS To Monitor Coral Reefs In The Park.** Based on the review of threats to coral reefs in the Park (Table 3), specific management-driven questions were formulated and the data needed to answer each question (i.e., the vital signs) were identified. This information is described below, summarized in Table 4, and a hypothetical example of the data to be collected is shown in Figure 5.

In reviewing the vital sign (VS) categories below (some of which require further refinement), bear in mind that staff are few, so a practical, management-driven approach is desired: what is the question and what information is needed to answer it? However, all important issues should be included, even if they exceed current capabilities of the Park or its partners. The plan should also be broad enough to encompass unanticipated threats.

It is worth highlighting that NPSA does not currently have the resources to fully implement all the vital signs listed below. In particular, two important vital signs are identified as 'un-met needs': monitor the subsistence fishery annually and monitor illegal fishing. These deficiencies will help NPSA prioritize future proposals.

### Threats common to all 3 NPSA Park units

#### **Threat T1:** Fishing pressure

**Monitoring question:** What are harvest trends in subsistence fisheries in the Park?

**VS 1:** Trends in (a) harvest quantity, (b) composition, and (c) catch-per-effort in each Park unit are currently unavailable but need to be collected to establish a benchmark against which future changes can be compared. Although harvests should be monitored regularly, NPSA will begin by monitoring each unit for a 1-yr period, at approximately 3-year intervals, because the high level of effort and personnel required exceed NPSA's current capacity to conduct surveys on three different islands annually. For example, it is generally necessary to monitor fisheries over an extended period of time (often one year) to determine fishing effort, because fishing effort is not equal during all hours of the day or night, or during all days of the week, or months of the year. NPSA's inability to conduct fisheries surveys more frequently at this time is thus identified as an 'unmet' need.

**Monitoring question:** What is the extent of illegal (commercial) fishing?

**VS 2:** Although this is an enforcement problem, it is an important issue particularly on Tutuila Island where stocks may be overfished – it has been estimated that 9% of fish sold in local markets is taken illegally by artisanal fishermen in the Park (Page 1998). However, the area where this nighttime fishing occurs is remote and roadless, there is no emergency support at night if a boating accident occurs, and NPSA currently lacks an enforcement capability. VS-2 is thus identified as an 'unmet' need at present.

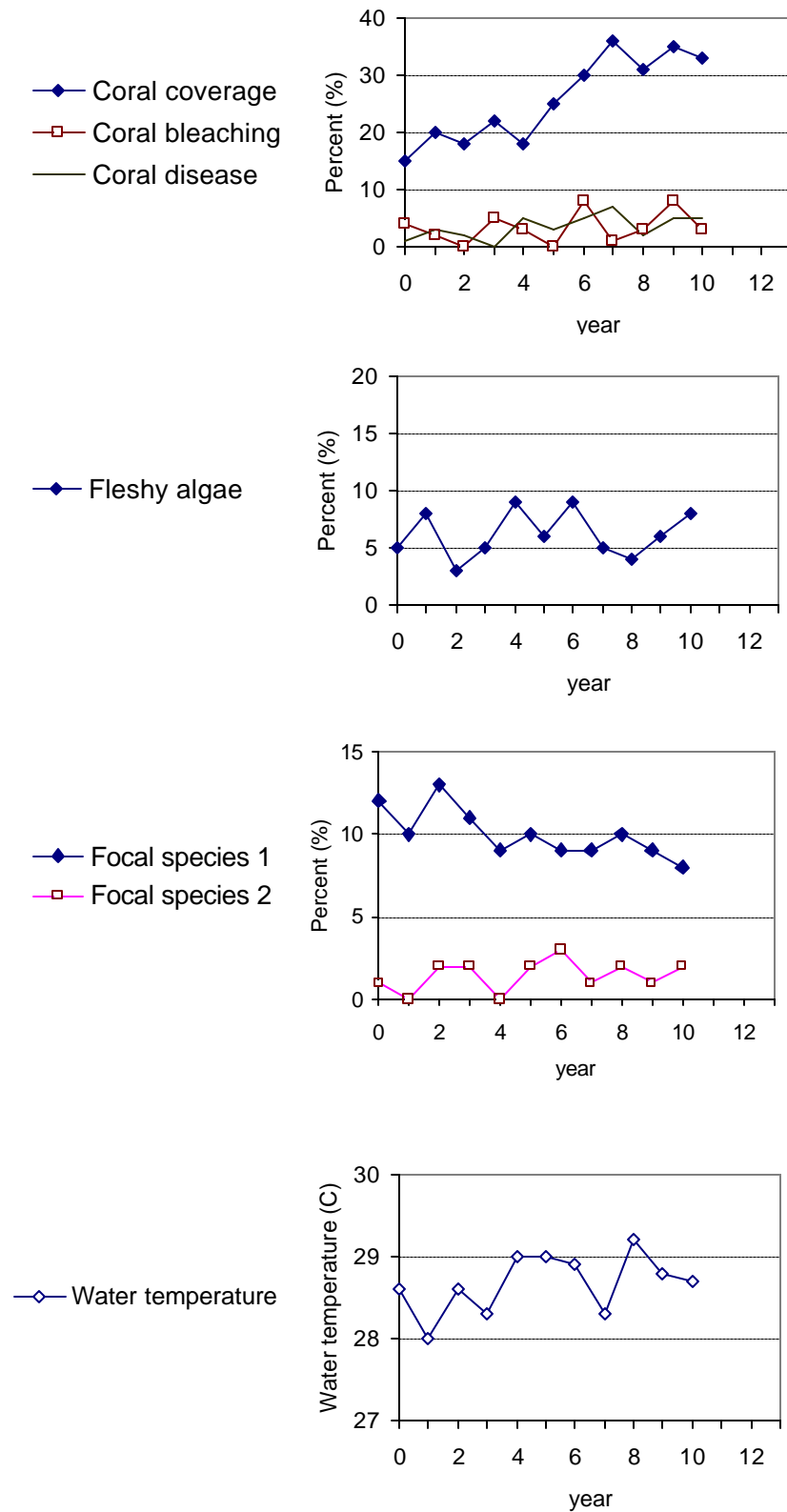
**Monitoring question:** Are reef resources being harvested at sustainable rates?

**VS 3:** Fishery-independent trends in abundance and size of selected fish and

**TABLE 4** Workshop recommendations for a 'vital signs' monitoring program in NPSA, including elements that should be measured regularly (at least yearly), less frequently, or as 'one-time' baseline sampling for possible future comparisons. It is recognized, however, that the frequency of sampling may be dictated by the observed stress or process. For example, if coral diseases become severe, monthly monitoring may be needed.

| Ecosystem component | Vital Sign | Regular monitoring (at least yearly)   | Low frequency monitoring                        | Baseline information  |
|---------------------|------------|--|---|---|
| Subsistence harvest | 1a         | Harvest quantity   |   |   |
|                     | 1b         | Harvest composition  |   |   |
|                     | 1c         | Catch per effort   |   |   |
|                     |            |  |   |   |
| Illegal fishing     | 2          | To be determined   |   |   |
|                     |            |  |   |   |
| Fish                | 3          | Abundance of selected harvested and ecologically important species, and family groups for others | inventory and relative abundance of all species | reference collection  |
|                     |            |  |   |   |
| Invertebrates       | 4a         | Giant clam abundance   | inventory and relative abundance                | reference collection  |
|                     | 4b         | Crown-of-thorns starfish abundance   |   |   |
|                     | 4c         | Sea urchin abundance   |   |   |
|                     | 4d         | Other ecologically or economically important species   |   |   |
|                     |            |  |   |   |
| Corals              | 5a         | Cover by type (growth form, common species, etc.)  | diversity, size, recruitment                    | maps, GIS, coral condition video                                      |
|                     | 5b         | Bleaching  |   |   |
|                     | 5c         | Disease  |   |   |
|                     |            |  |   |   |
| Algae               | 6          | Cover by type (turf, coralline, etc.)  | inventory and relative abundance                | video   |
|                     |            |  |   |   |
| Water quality       | 7a         | Temperature  | land use survey, salinity, oxygen               | sediments (nutrients contaminants, % land origin, N14/15 ratio, etc.) |
|                     | 7b         | Turbidity  |   |   |
|                     |            |  |   |   |
| Weather             | 8a         | Air temperature  |   |   |
|                     | 8b         | Rainfall   |   |   |
|                     | 8c         | Other meteorological data  |   |   |
|                     |            |  |   |   |
| Human use           | 9          | Visitor use surveys  |   |   |

**Figure 5.** Example of proposed product for monitoring Vital Signs.



invertebrates harvested in fishery. The fishery surveys (VS 1) will also provide information about fishing pressure (catch-per-effort, fish size, etc.). Additionally, the local fisheries agency (DMWR) is in the process of re-starting their efforts to monitor the island-wide harvest of coral reef fishes and invertebrates, although not specifically within NPSA. We will attempt a high level of inter-agency cooperation in these efforts.

**Monitoring questions:** What is the harvest of endangered and threatened green and hawksbill sea turtles? What is their abundance and how many nest in NPSA?

**Not a VS:** Due to the scarcity of turtles in Park waters and a lack of knowledge about their complex migrations and residence patterns, it is not feasible to monitor turtle abundance, nesting or harvest in NPSA except on an opportunistic basis.

**Threat T2:** Natural changes to the environment due to physical and biological processes (hurricanes, global warming, coral bleaching and disease), as well as cumulative natural or anthropogenic impacts.

**Monitoring question:** Are the coral reef ecosystems in the Park healthy (i.e., what are changes in condition over time)?

**VS 3:** Fish: fishery-independent trends in abundance of selected harvested and ecologically important species (e.g., herbivores), and family groups for remaining species; lower frequency inventory or monitoring of species diversity.

**VS 4:** Macro-invertebrates: trends in abundance of selected ecologically important or harvested species: (a) giant clams, (b) crown-of-thorns starfish, (c) sea urchins, etc.

**VS 5:** Corals: trends in (a) condition (coral cover by type, growth form, etc., and size frequency of selected species), (b) disease, (c) bleaching; lower frequency inventory or monitoring of species diversity.

**VS 6:** Algae: trends in cover by type (turf, coralline, etc., and fleshy algae as an indicator of nutrient enrichment or overharvest of herbivorous fishes); video transects for future comparisons; lower frequency inventory or monitoring of species diversity.

**VS 7:** Water quality: (a) water temperature and (b) turbidity; lower frequency monitoring of land use, salinity, dissolved oxygen; baseline data on sediments, nutrients, N14/15, etc.

**VS 8:** Weather: (a) air temperature, (b) rainfall, and other meteorological data.

**VS 9:** Visitor abundance and uses of Park

### Additional threats to specific Park Units

**Threat T3 (Tutuila):** Diverse impacts resulting from rapid human population growth.

**Monitoring question:** Is the rapid growth of the human population spilling over into the Park and affecting the health of the coral reef ecosystem there (eg, nutrient increases due to human or piggery wastes, trash disposal, sedimentation from poor land-use practices)?

**Not a VS:** This issue is addressed in Threat T2 above. Additionally, NPSA is not located where most human expansion is occurring.

**Threat T4 (Ofu):** Recreational impacts in Ofu lagoon

**Monitoring question:** What is the extent of coral damage due to snorkelers or divers?

**(VS 5):** Index of coral breakage; however, it may be difficult to detect such small-scale coral damage, so a recommended approach is to take video transects for future comparisons.

**Monitoring question:** Is tourism causing nutrient enrichment in Ofu lagoon due to septic field leaching?

**(VS 6):** Because the lagoon is thoroughly flushed with offshore waters (except at low tide), it is unlikely that nutrient levels there would increase significantly, but monitoring the amount of fleshy algae in the lagoon (VS 6), as well as estimating annual numbers of visitors to the lagoon (VS 9) would be useful.

**Threat T5 (Ofu):** Crown-of-thorns starfish (COTS) predation on corals in Ofu lagoon (the lagoon is a small special management area; for unknown reasons COTS are often found in low numbers around Ofu and Olosega islands, but not elsewhere since the COTS invasion in the 1970's).

**Monitoring question:** Do numbers of COTS exceed a threshold level in the lagoon?

**(VS 4):** Relative abundance index of COTS; determine what is a threshold number.

**Threat T6 (Ofu):** Pollution seepage from village dump adjacent to Park.

**Monitoring question:** Are pollutants affecting Ofu lagoon?

**Not a VS:** Due to tidal flushing, pollutants, if present, are probably at low levels, but baseline sampling is needed to determine present conditions and for future comparisons; it may suffice that a local agency (ASEPA) plans to include Ofu lagoon fish and substrates in their toxicity sampling program.

**Threats (Ta'u):** Additional issues are not identified at this time; see 'All Park Units' above.

**WHAT'S NEXT ?** After refinements to the vital signs above, the next steps will be to evaluate appropriate methods and sampling designs, and to document sampling protocols. Additionally, National Parks with coral reefs in the Pacific region will prepare an integrated vital signs monitoring and implementation plan, followed by a handbook of protocols.

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## APPENDIX 1. Workshop Participants

|                     |                               |                      |                                 |
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